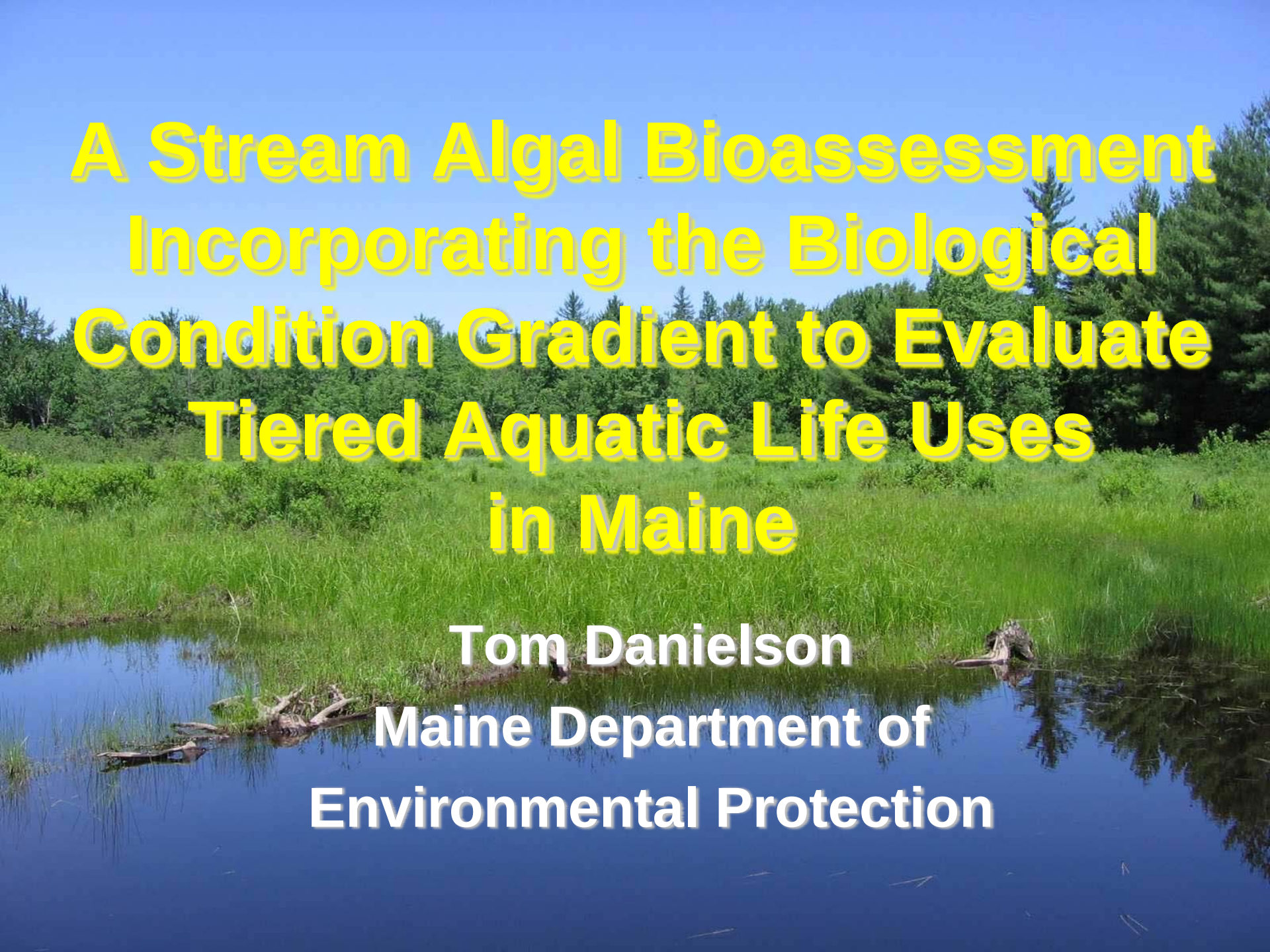
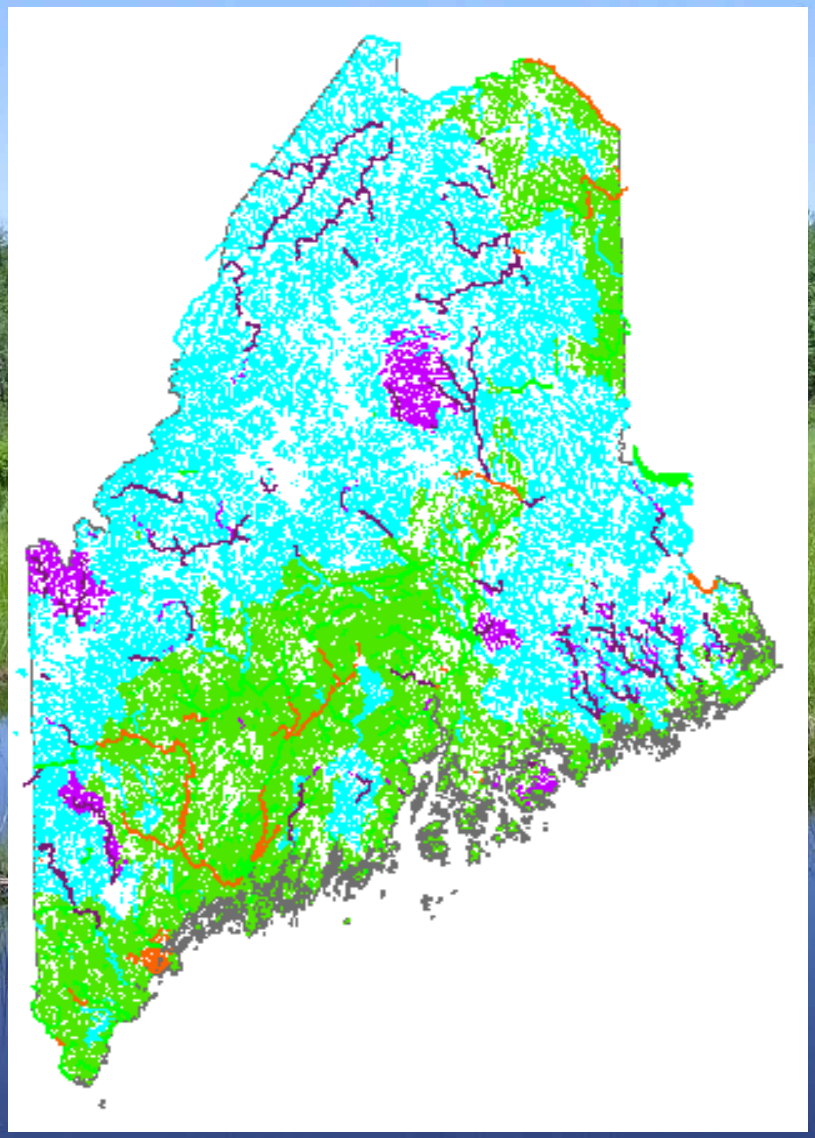


A Stream Algal Bioassessment Incorporating the Biological Condition Gradient to Evaluate Tiered Aquatic Life Uses in Maine

Tom Danielson
Maine Department of Environmental Protection

Stream Classes



% OF LINEAR MILES OF STATUTORY CLASSIFICATIONS

Class AA = 6%

Class A = 45%

Class B = 47%

Class C = 2%

(Class C ~8-10% for large rivers and urban streams)

Maine DEP's Biological Monitoring Unit

- **Determine if streams, rivers, and wetlands are attaining aquatic life criteria**
- **Provide water quality data for many other programs**
- **>25 years with stream macroinvertebrates.**
- **>10 years with stream and wetland algae, and wetland macroinvertebrates.**

Leon Tsomides

Beth Connors

Jeanne DiFranco

Tom Danielson

Foundations of Algal Model

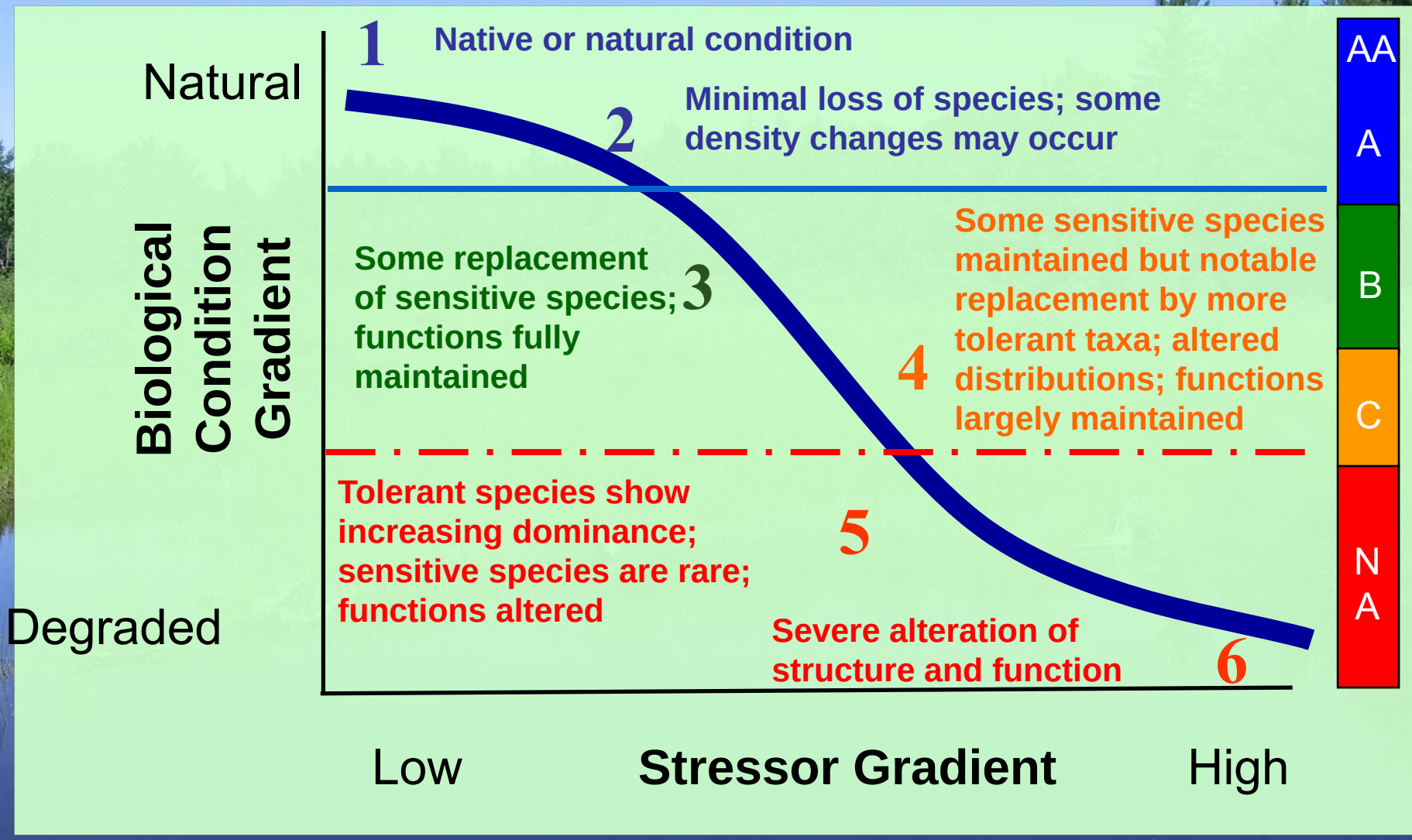
- **Maine's narrative aquatic life criteria**
- **U.S. Environmental Protection Agency's Biological Condition Gradient (BCG)**
  - **Davies, S.P. and S.K. Jackson (2006) The Biological Condition Gradient: A Descriptive Model for Interpreting Change in Aquatic Ecosystems. *Ecological Applications* 16(4):1251–1266**

Aquatic Life Criteria

Class AA **Class A**	as naturally occurs
Class B	support all aquatic species indigenous to the receiving water; no detrimental changes to the resident biological community
Class C	support all fish species indigenous to the receiving water; maintain the structure and function of the resident biological community

Non-attainment (NA) stream does not meet minimum criteria

Biological Condition Gradient (BCG)



Class A Stream

Babel Brook, T5 R9 NWP

Stoneflies

Dragonflies &
Damselflies

Mayflies

Beetles

Midges

Caddisflies

Color Code
Sensitive
Intermediate
Tolerant

1 inch

Class B Stream

Eddy Brook, New Gloucester

Craneflies

Caddisflies

Non-Insects

Beetles

Midges

Stoneflies

Blackflies

Mayflies

Color Code

Sensitive

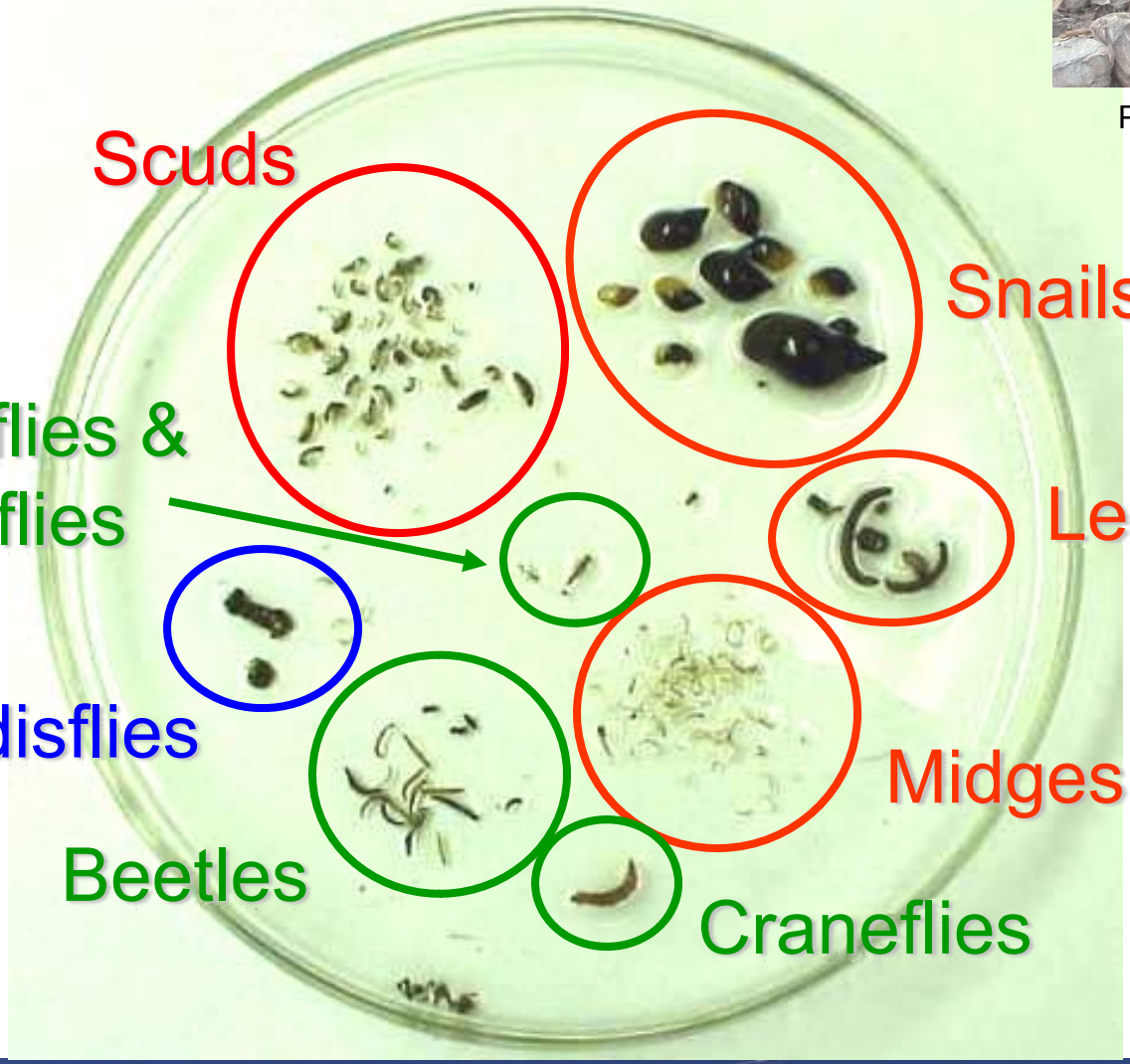
Intermediate

Tolerant

1 inch

Non-Attainment Stream

Penjajawoc Stream, Bangor



Color Code

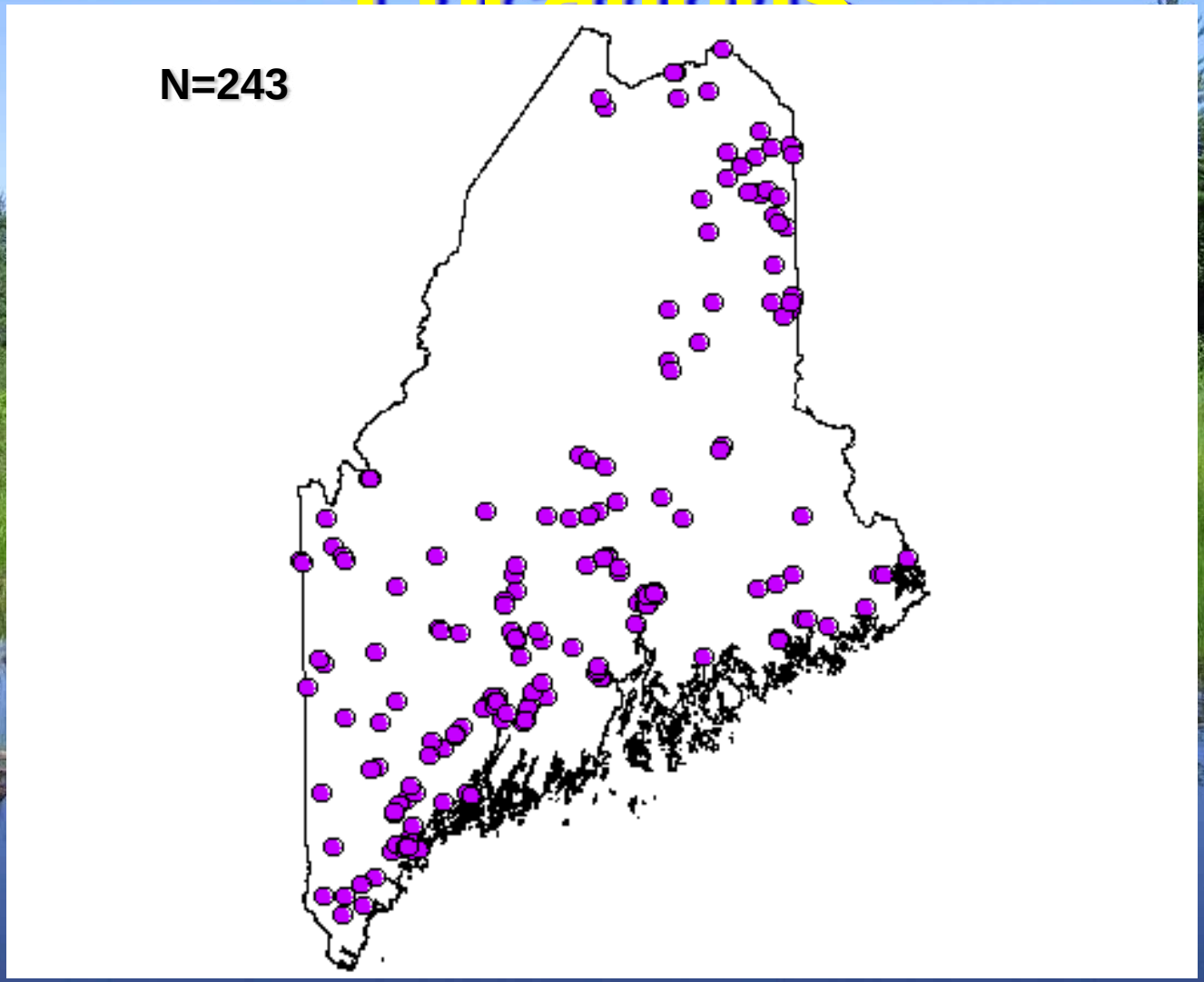
Sensitive

Intermediate

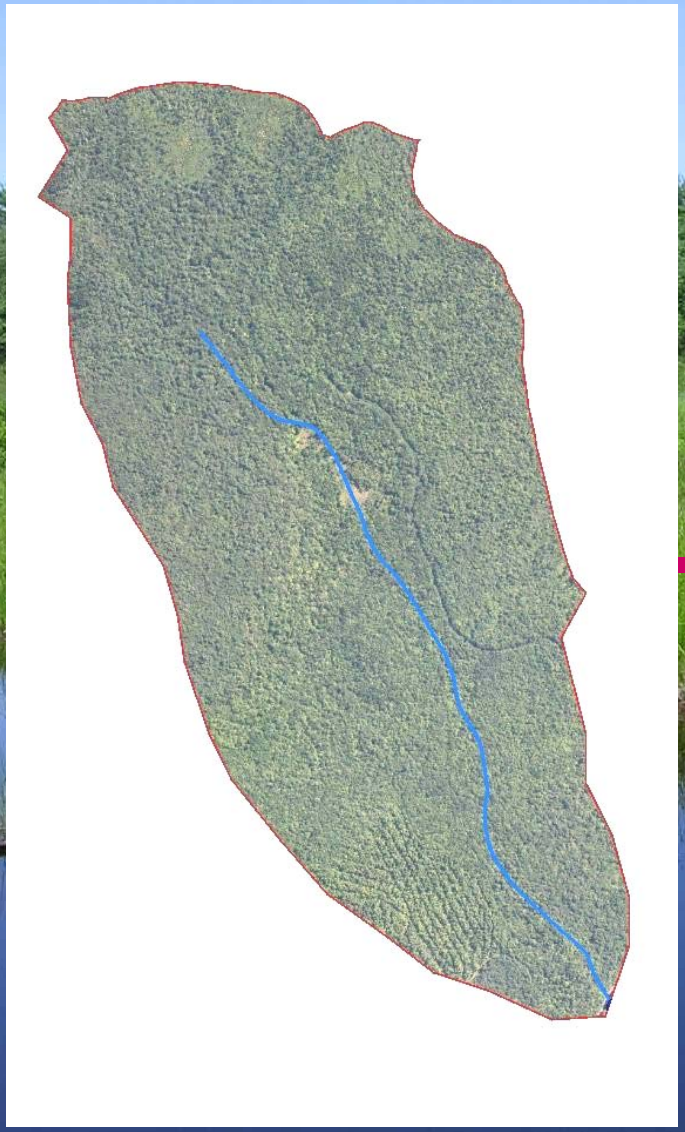
Tolerant

1 inch

Stream Algal Sample Locations



Range of Condition

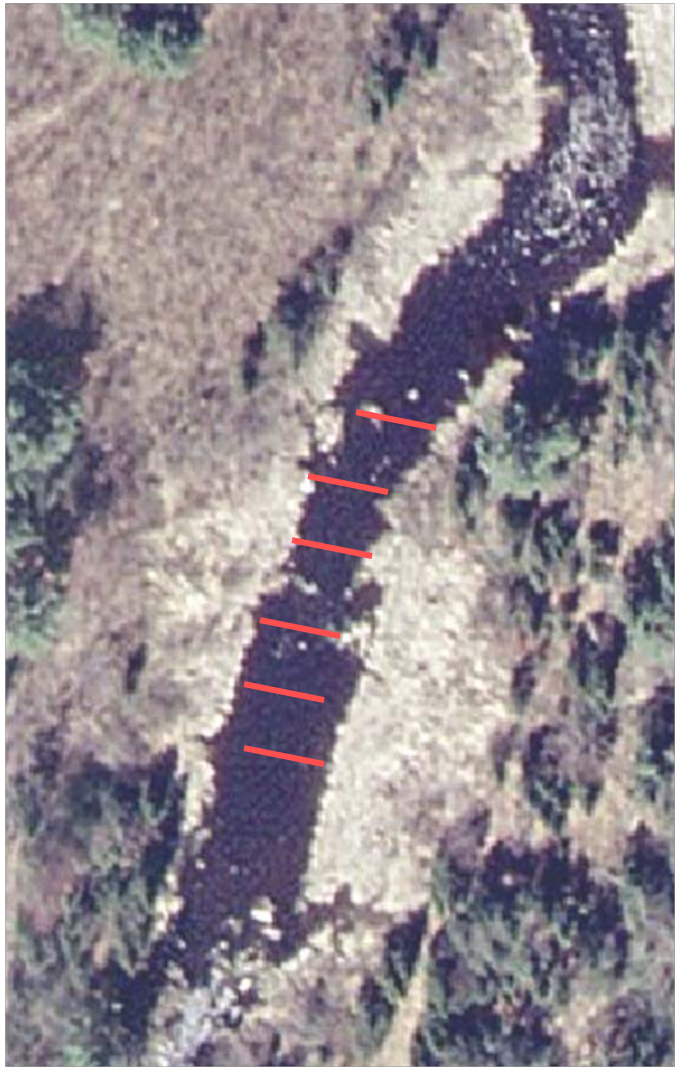


Minimally Disturbed Reference Sites

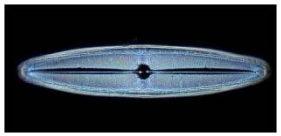
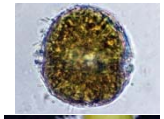
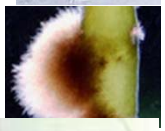
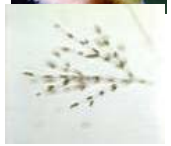
- **>95% of upstream watershed is forest & wetlands**
- **No point source discharges**
- **No dams**
- **No atypical source of pollution (e.g., iron mining)**

Tom Danielson, Maine DEP

Natural Substrate Samples

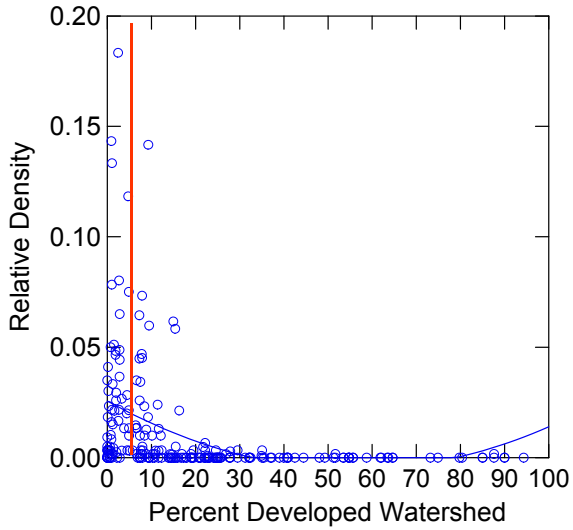


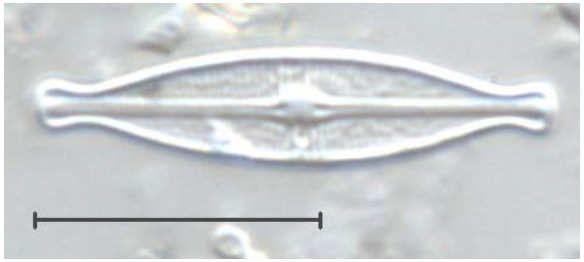
Taxonomic Diversity

1999-2008 Stream Samples	Genera	Species/ Forms
 Diatoms	90	806
 Green Algae	59	226
 Cyanobacteria	51	122
 Euglenoids	4	13
 Yellow-green Algae	5	7
 Dinoflagellates	2	3
 Red Algae	4	2
 Chrysophytes	5	4

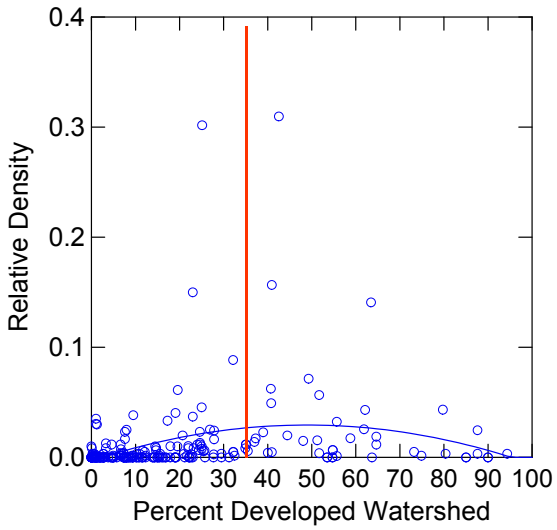
Weighted Average Optima

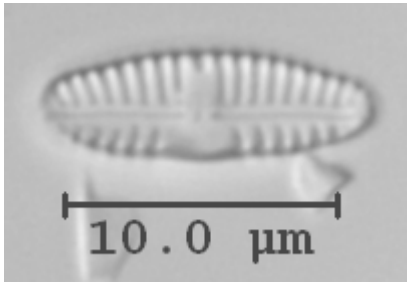
Brachysira microcephala



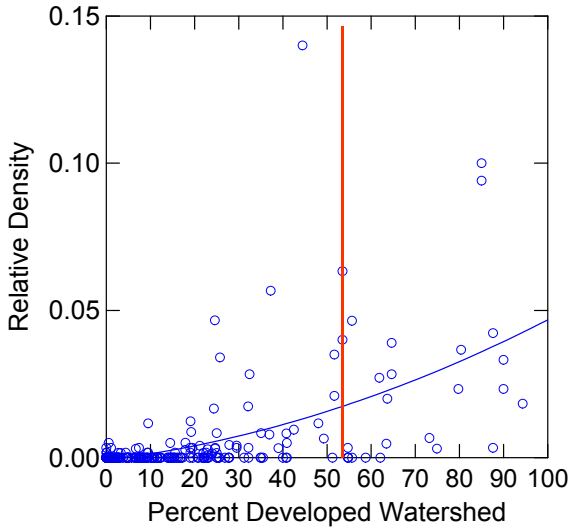


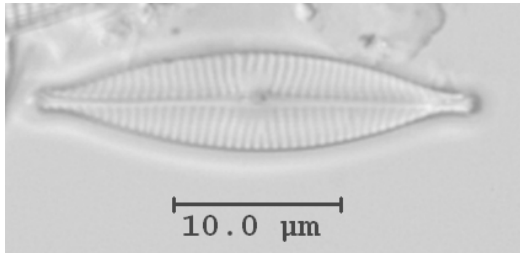
Reimeria sinuata





Navicula gregaria

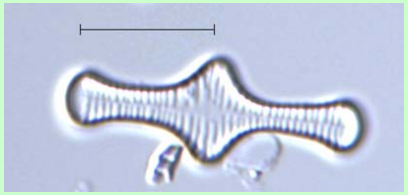




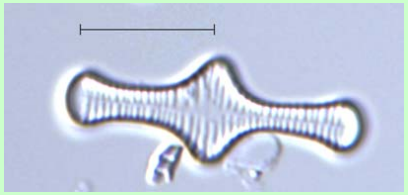
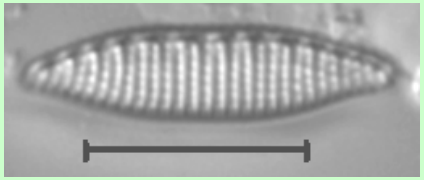
Weighted Average Optima

Environmental Variable		
Percent of Watershed that is Forest or Wetland		
Percent of Watershed that is Impervious Surface		
Specific Conductance		
Total Nitrogen		
Total Phosphorous		

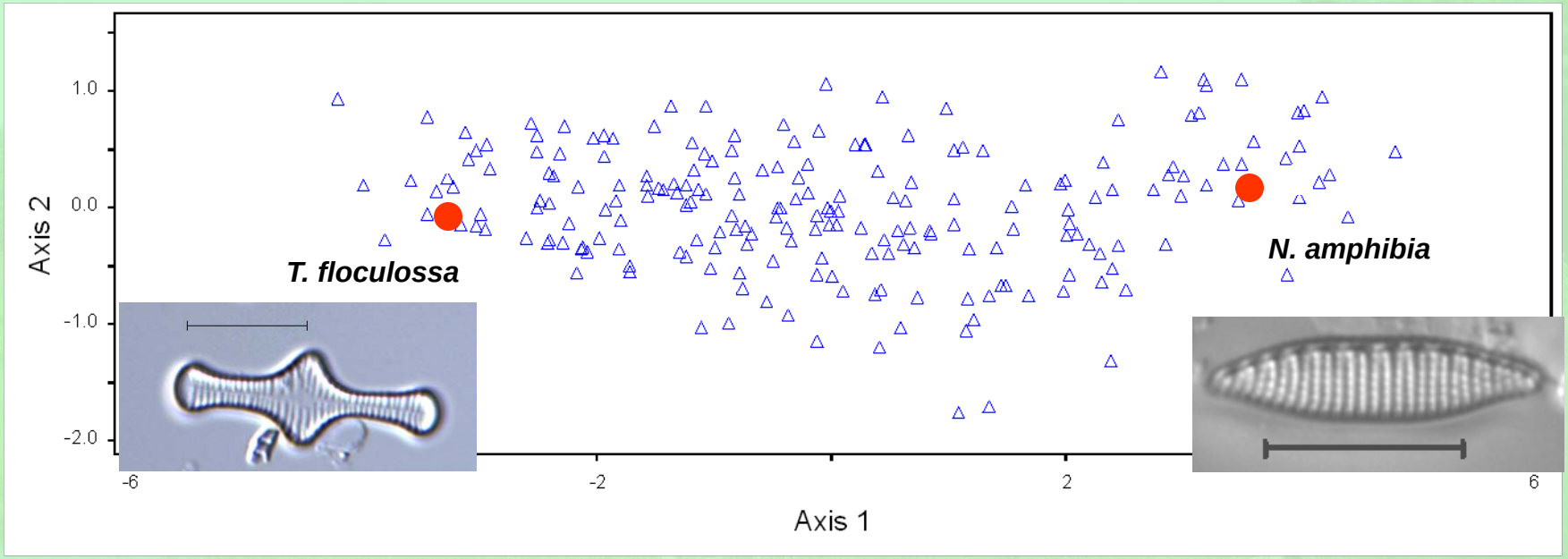
Weighted Average Optima

Environmental Variable	*Tabellaria flocculosa* 	
Percent of Watershed that is Forest or Wetland	98%	
Percent of Watershed that is Impervious Surface	1%	
Specific Conductance	22 μS/cm	
Total Nitrogen	331 ppb	
Total Phosphorous	8 ppb	

Weighted Average Optima

Environmental Variable	*Tabellaria flocculosa* 	*Nitzschia amphibia* 
Percent of Watershed that is Forest or Wetland	98%	16%
Percent of Watershed that is Impervious Surface	1%	40%
Specific Conductance	22 μS/cm	475 μS/cm
Total Nitrogen	331 ppb	711 ppb
Total Phosphorous	8 ppb	39 ppb

PCA Identified Major Pattern in Species Optima



- **Axis 1 represents 86% of variance**
- **Rescaled axis to 1 (most sensitive) to 100**
- **Grouped taxa into Sensitive (<32.2), Intermediate (32.2-60), and Tolerant (>60).**

Candidate Metrics

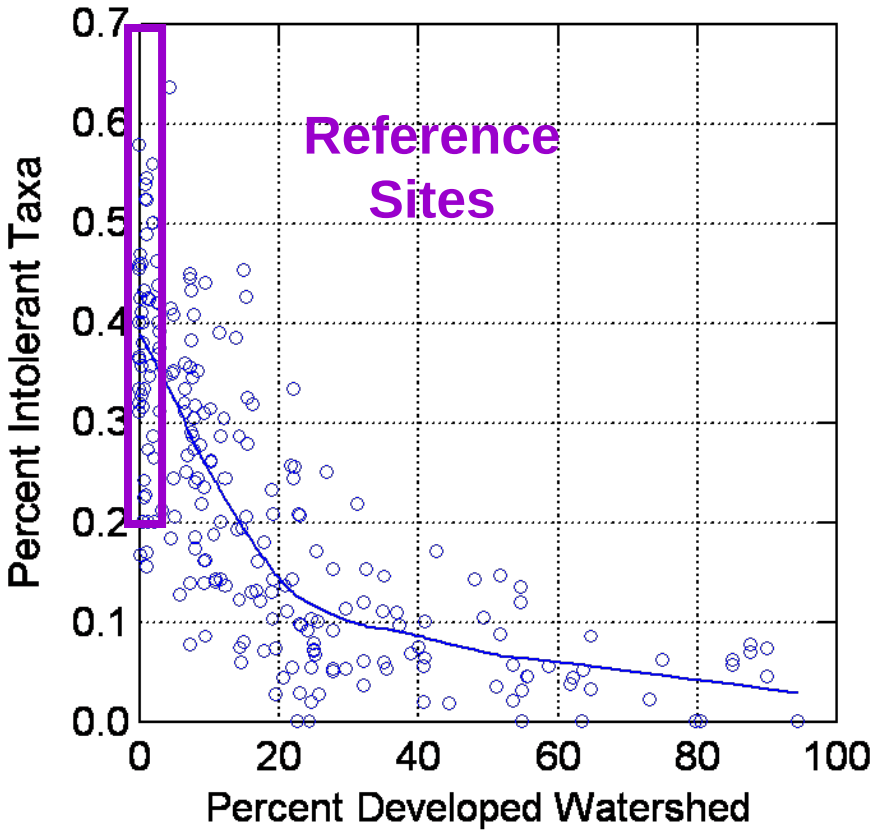
FROM LITERATURE (Examples)

- **Relative abundance**
  - motile diatoms
  - polysaprobic diatoms
  - eutraphentic diatoms
  - low oxygen diatoms
  - salt tolerant diatoms
  - dominant species
- **Total Richness**
- **Shannon-Wiener Diversity Index**

NOVEL (Examples)

- **Relative richness**
  - Sensitive taxa
  - Tolerant taxa
  - *Brachysira, Eunotia, Tabellaria, and Anomoneis* (BETA)
  - Bacillariaceae, Catenulaceae, Rhoicospheniaceae, and Surirellaceae (BCRS)
- **Relative biovolume**
  - Sensitive taxa
  - Tolerant taxa

Algal Metrics



- Spearman rank correlation (ρ) = -0.81 (P<0.001)

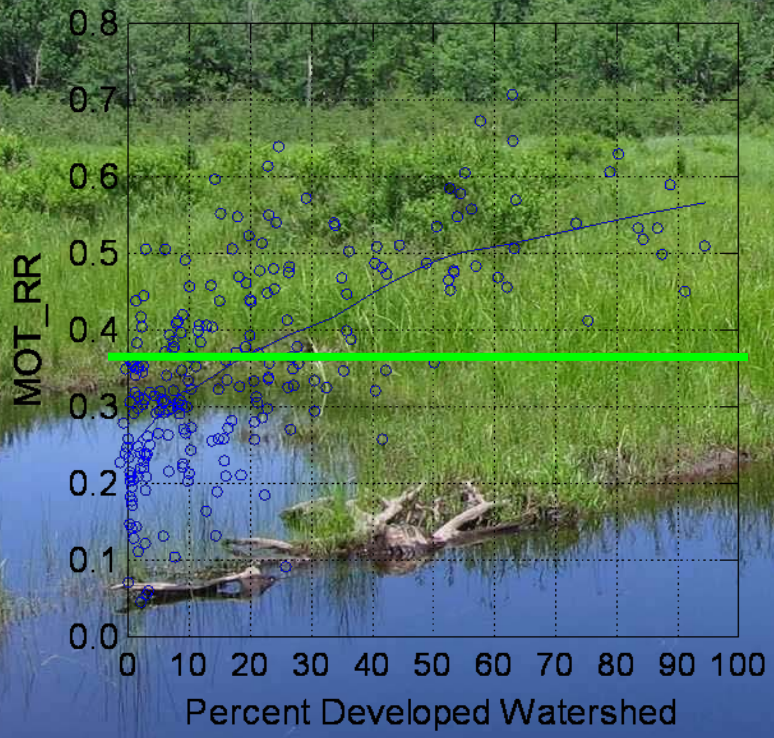
- Mann-Whitney U test statistic = 865

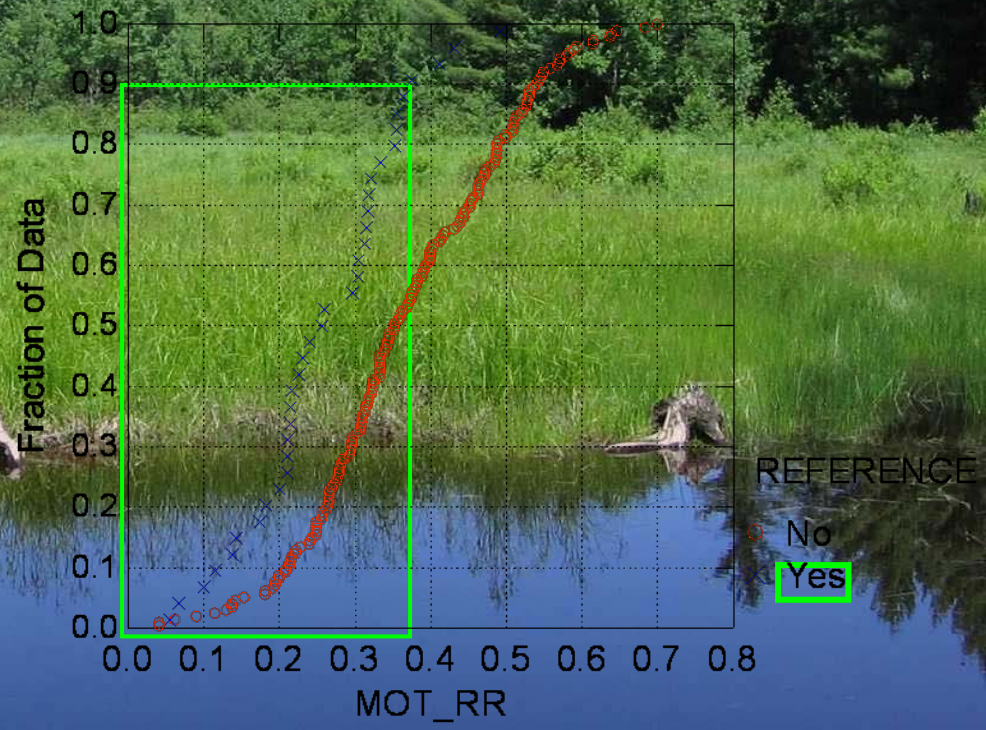
  - χ^2 approximation = 37.830 with 1 df (P<0.001)

Materials given to biologists

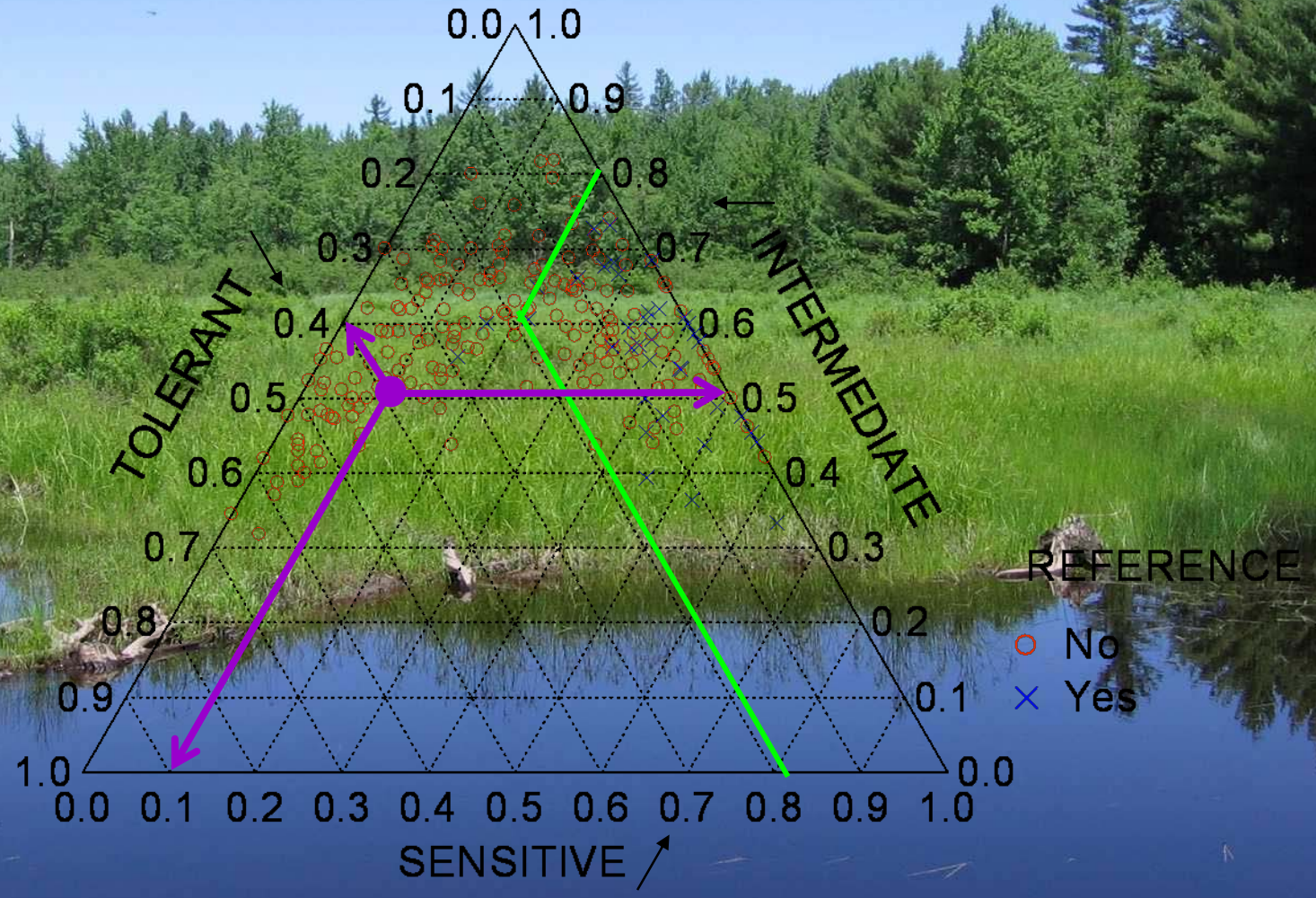
- Summary variables and metrics for each sample (n=230)
- Taxa lists with abundances, relative abundances, tolerances, etc. for each sample
- Samples identified by random number
- Only biological data provided
- Report with metric graphs and descriptions

Example of Graphs Provided to Biologists





Relative Richness of Sensitive, Intermediate, and Tolerant Algae



Class Assignments

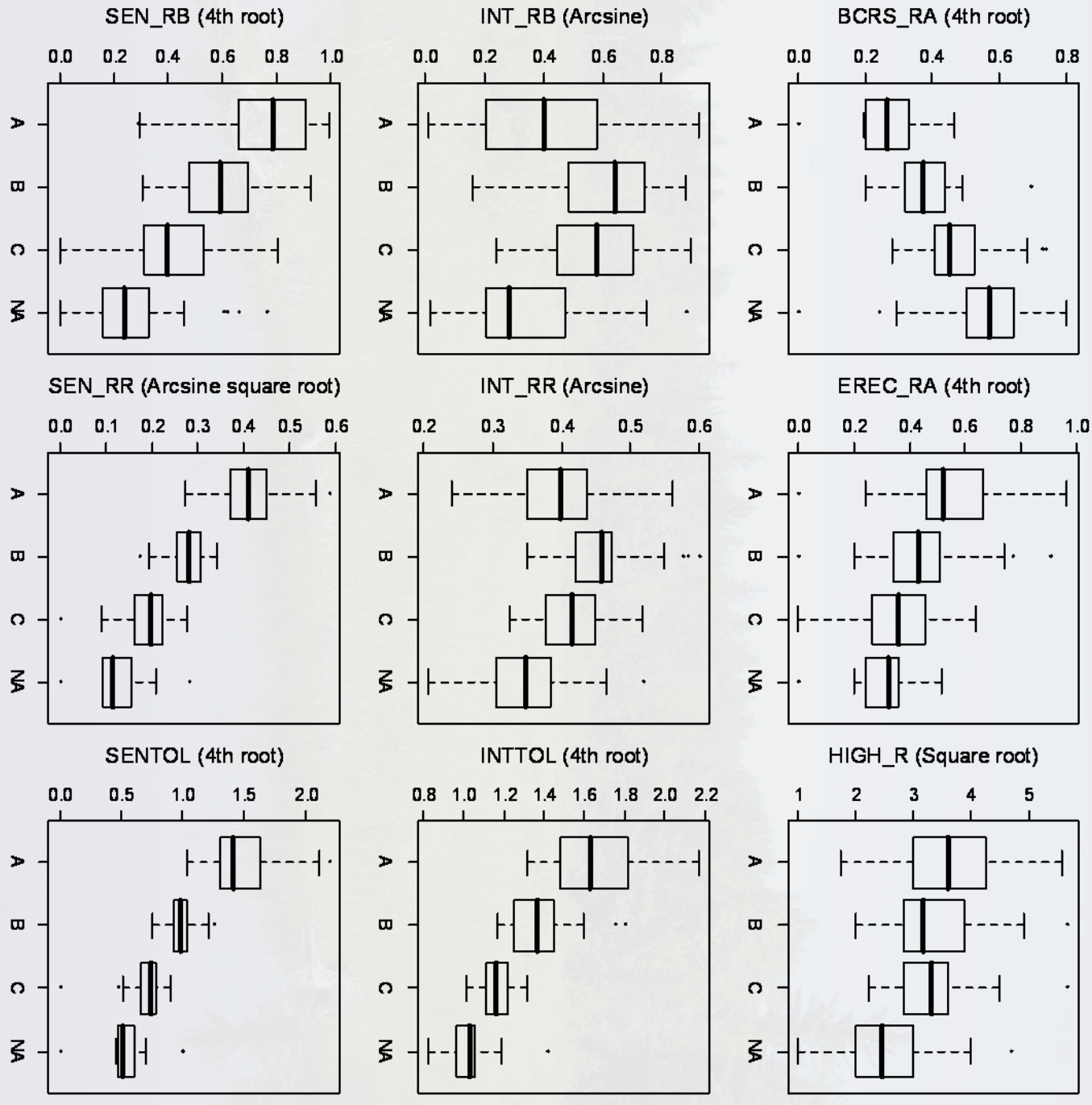
- **Biologists independently evaluated samples (blind)**
  - **Maine class (A, B, C, NA)**
  - **BCG Tier (1-6)**
- **Biologists later compared results and made consensus assignments.**

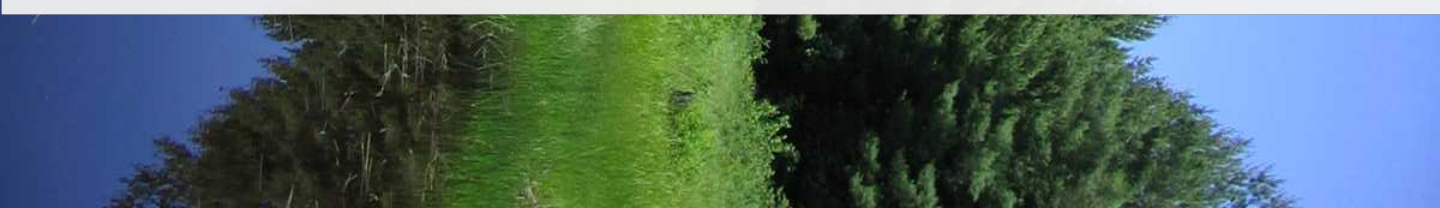
Biologist Class Assignments

- **105 Class A, 46 Class B, 46 Class C, and 33 non-attainment.**
  - **53% unanimous**
  - **22% 4 vs. 1 (differed by one class)**
  - **20% 3 vs. 2 (differed by one class)**
  - **5% differed by more than one class**

Discriminant Analysis Model

- Predicts group membership (i.e., A, B, C, NA) based on linear combination of metrics.
- 230 samples
  - 150 used to build the model (training set)
  - 80 used to test the model (test set)
- Metrics selected with backward stepwise selection.
- Identified and removed metrics with high within-group correlations (r>0.70).


SEN_RB (4th root)
0.0 0.2 0.4 0.6 0.8 1.0
INT_RB (Arcsine)
0.0 0.2 0.4 0.6 0.8
BCRS_RA (4th root)
0.0 0.2 0.4 0.6 0.8
SEN_RR (Arcsine square root)
0.0 0.1 0.2 0.3 0.4 0.5 0.6
INT_RR (Arcsine)
0.2 0.3 0.4 0.5 0.6
EREC_RA (4th root)
0.0 0.2 0.4 0.6 0.8 1.0
SENTOL (4th root)
0.0 0.5 1.0 1.5 2.0
INTTOL (4th root)
0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2
HIGH_R (Square root)
1 2 3 4 5
A
B
C
NA



95% Correct Model Performance with Training Data (n=150)

(Row percents with number of samples in parentheses)

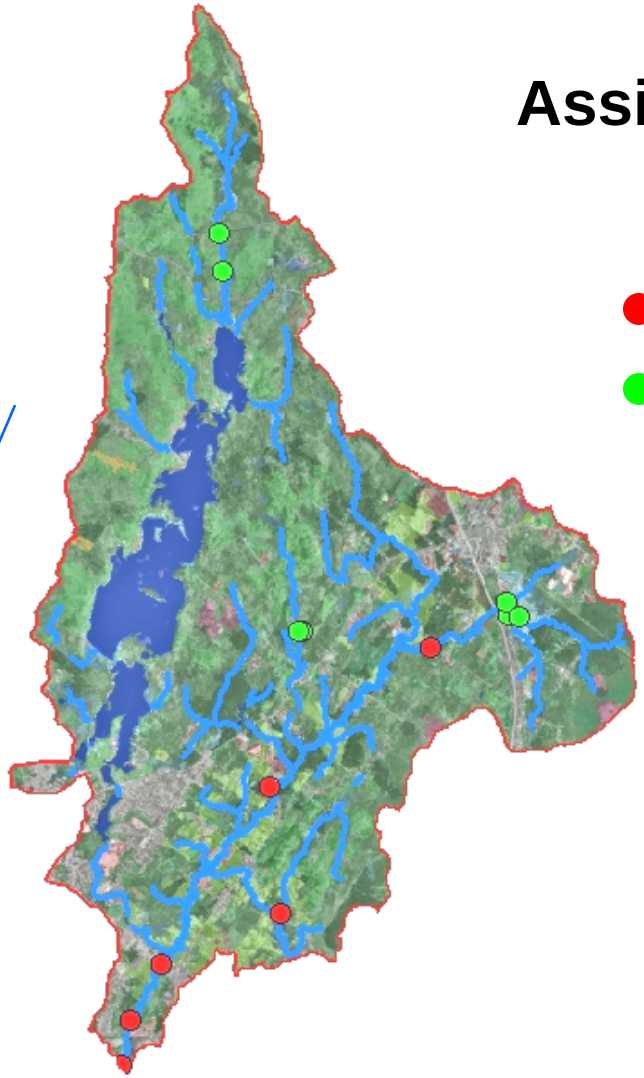
	Algal LDM Predicted Class			
	A	B	C	NA
a priori Class A	97% (67)	3% (2)	--	--
a priori Class B	3% (1)	90% (27)	7% (2)	--
a priori Class C	--	--	93% (28)	7% (2)
a priori NA	--	--	--	100% (21)

91% Correct Model Performance with Validation Data (n=80)

(Row percents with number of samples in parentheses)

	Algal LDM Predicted Class			
	A	B	C	NA
a priori Class A	97% (35)	3% (1)	--	--
a priori Class B	13% (2)	81% (13)	6% (1)	--
a priori Class C	--	13% (2)	88% (14)	--
a priori NA	--	--	9% (1)	91% (10)

Watershed Assessment
Pleasant River, Windham

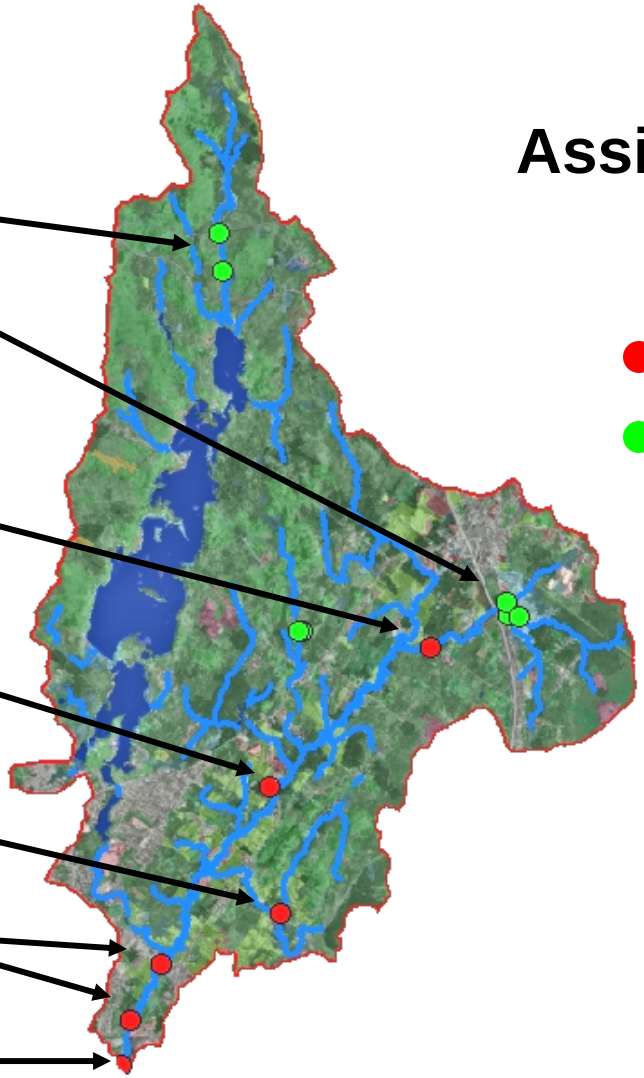


Direction of flow

Assigned Goal is Class B

- Stream sample
- Wetland sample

BCG is a Crosswalk



Wetland Bugs: A

Wetland Bugs: A/B

Bugs: B
Algae: B

Algae: B

Bugs: B

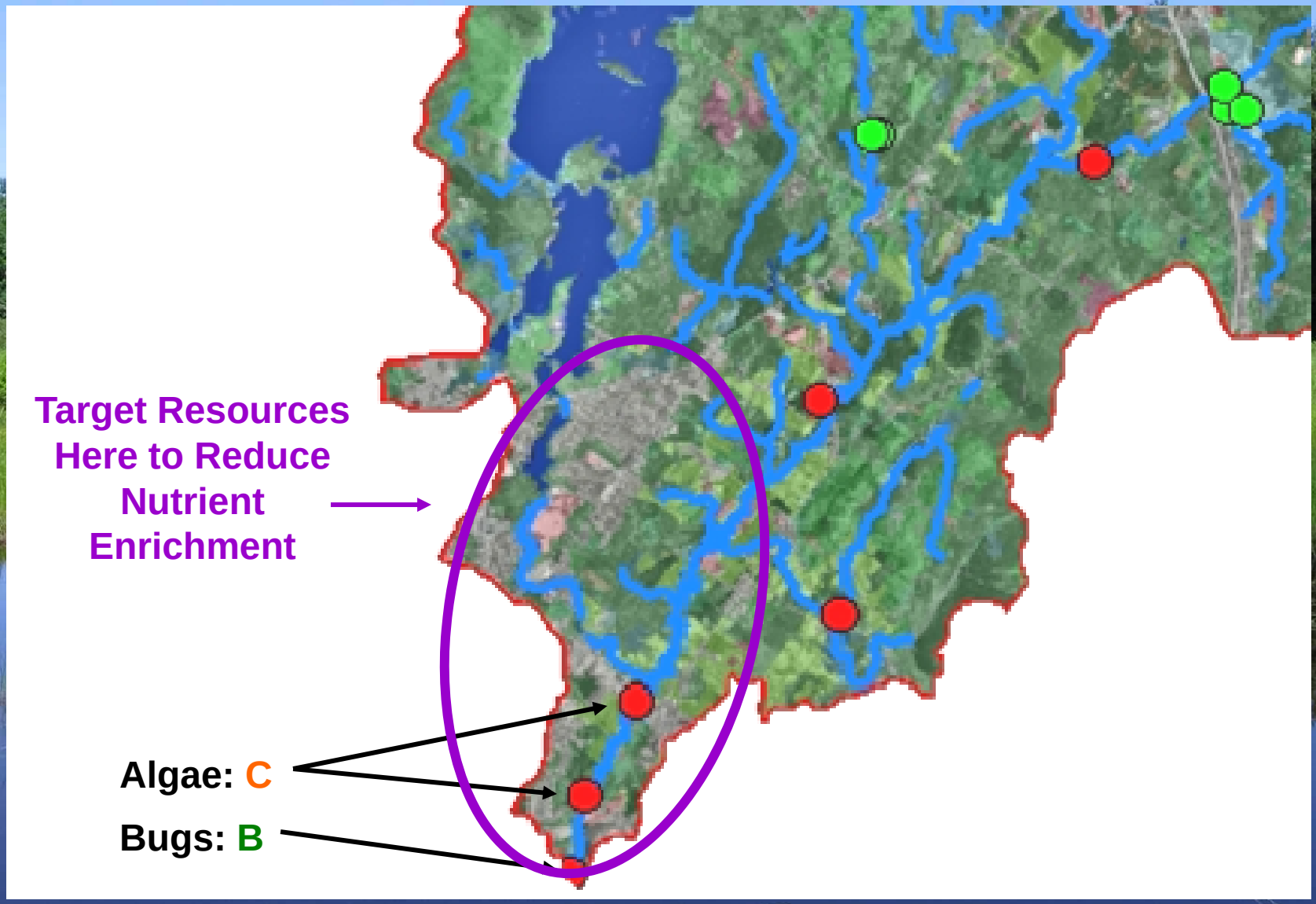
Algae: C

Bugs: B

Assigned Goal is Class B

- Stream sample
- Wetland sample

BCG Helps Targets Resources



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  - U.S. Environmental Protection Agency
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  - Dave Courtemanch
  - Leon Tsomides
  - Jeanne DiFranco
  - Beth Connors
  - Susanne Meidel
  - Chris Halsted
  - Mike Smith (now with OGIS)
  - >50 interns, conservation aides, Americorps, and volunteers
- Partners
  - Houlton Band of Maliseet Indians
  - Manomet Center for Conservation Sciences
- PhD Committee (UMaine)
  - Dr. Cynthia Loftin, advisor
  - Dr. Francis Drummond
  - Dr. Susan Brawley
  - Dr. R. Jan Stevenson (Michigan State University)
  - Dr. Dave Courtemanch (Maine DEP)